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INTERNATIONAL APPLICATION **PUBLISHED** UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [5]: **A61B 17/36, B44C 1/22** **A1**

(11) International Publication Number: **WO 92/19165**

(43) International Publication Date: 12 November 1992 (12.11.92)

(21) International Application Number: **PCT/GB92/00739**

(22) International Filing Date: **22 April 1992 (22.04.92)**

(30) Priority data:
9108777.5 24 April 1991 (24.04.91) GB

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(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CI, CH (European patent). CI (OAPI patent), CM (OAPI patent), CS. DE, DE (European patent), DK, DI (European patent). ES, ES (European patent), Fl, F (European patent). GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (European patent)HU, IT (European patent), JP, KP, KR, LK, LU, LLB (European patent), MC (European patent), MG, ML (OAPI patent), MN, MR (OAPI patent). MW, NL, NL (European patent), NO. PL, RO. RU, SD. SE, SE (European patent), SN (OAPI patent), TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: **ERADICATION OF MARKS AND STAINS BY LASER**

(57) Abstract

A method of and apparatus is described for eradicating marks and stains at or beneath the surface of a substrate. The technique involves the use of a variable wavelength pulsed laser and an optical fibre delivery system to direct a spot of laser light at the treatment site. The laser produces an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds. at an energy level in the range of 0.5 to 5 Joules at a wavelength in the range of 400 to 900 nanometres. The output may consist of a single pulse or a sequence of pulses with a repetition rate selectable from 1 to 20 Hz. Marks in many different material may be eradicated using this technique. Examples are leather, wood, plastics and skin lesions such as tattoos and "port wine stains".

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ERADICATION OF MARKS AND STAINS BY LASER

THIS INVENTION concerns a method of and apparatus for eradicating marks and stains by laser and i s particularly though not exclusively concerned with removal of pigmentation at or beneath the surface of a substrate.

Applications of the method are #nanifold, such as removal of marks and stains in hides or made up rticles of leather, from wood especially in articles of furniture, fro textiles and articles of clothing, and any application where pigm nted or other marks or stains require elimination without damage to the surrounding substrate. A further example is the removal of skin le ions including pigmented lesions such as tattoo marks, moles, etc, anc$ vascular lesions such as "port wine" stains..

Attempts have been made to r emove pigmented marks using a Q-switched ruby laser. Such a lase generates a very short pulse duration in the region of 10 to 30 n no seconds and imposes power densities on the substrate in the region of 1,200 to 2,800 $GW\,m^{-2}$. Such power densities may cause d mage to the surrounding substrate. Furthermore, a Q-switched ruby laser cannot deliver its treatment. beam to the site using a flexible o tical fibre. This is due to the very high power densities generated, and an articulated arm must be used for delivery.

Additionally, ruby lasers operate on a single wavelength system, usually 693 nanometres.

An object of the present inv ntion is to provide a method of and apparatus for the eradicatcn of marks and stains, using a tunable laser which is effective in removal whilst operating at power densities far less than that generated by a Q-switched ruby laser, and with Ionger pulse duration, and wherein a flexible optical fibre may be used to deliver the treatment beam to the site.

According to the present invenhion there is provided a method of eradicating marks and stains at or beneath the surface of a substrate, comprising the step of directing at said surface, laser light generated by a variable wavelength pulsed laser, the laser operating to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

In a preferred method the laser produces a sequence of pulses with a repetition rate in the range of I to 20Hz.

Still further, the laser energy is preferably delivered to the surface . via a single or multiple core optical fibre having a core size in the range of 600 to 1500pm.

In this way, the fibre optic deliv system may be hand-held allowing for the adjustment of the spot 'size of the laser beam

on the surface, so that it can be selected within the range of 1 to 100mm in diameter.

The basic principle behind the rr ethod is that the laser is used to irradiate the site of the mark or st ain in the substrate, and the wavelength at which the laser operate s is chosen so that the mark or stain absorbs the radiation whit; t unmarked surrounding substrate absorbs only little and so is not damaged. In this way a selective effect is obtained. .

Further according to the present invention there is provided a pulsed laser apparatus for eradiciting marks and stains at - or beneath the surface of a substrate, the apparatus comprising a variable wavelength pulsed laser which is tun ble to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the rang of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nnometres.

The apparatus comprises a fibr e optic delivery system incorporating an optical fibre having a core size in the range 600 to 1500pm.

It is believed that the aforesaid method may be effected in many different applications such as the removal of pigmentation marks and stains at or beneath a translucefIt surface and also for creation of marks, for example, on self-colotred plastics material by removing pigmentation preferentially in selected areas thus to produce

identification marks. One example of such !application is an electrical cable having self-coloured sheathing which, 1 by the application by the laser light in accordance with the invention may be selectively marked.

Coloured substrates may ha\e a pattern or printing imposed thereon, by selective eradication] of pigmentation. These effects may be established at and/or just eneath the surface of the substrate thus to be visible thereat.

An embodiment of the metho1 in accordance with the invention will now be described in relz tion to the removal or reduction of skin lesions such as tattoo mark s and port wine stains.

A" tattoo mark is produced by !! a dark pigment (usually blue or black) introduced into the dermis. The particles of pigment are not removed by normal cellular activity and so the mark is permanent. The colour particles which make up the tattoo, usually absorb well at wavelengths in the red part of the spectrum corresponding to a wavelength in the range of 650 to 700nanometres. However, these wavelengths are not absorbec by normal unmarked skin and so are scattered such that the energy is dissipated over a relatively large area with little or no effect on normal tissue.

In the lesion itself the radiation is very efficiently absorbed and so the energy is concent -ated in or around the pigmented area.

The design of the laser system is such as to increase the discrimination between tissue which forms part of the lesion, and normal unmarked tissue. For example, pulsed energy is important! A pulse of energy is deposited in the effected tissue for a time which is short when compared with the thermal rel4ation time of the tissue. This means that the heat is generate locally and will not significantly spread by conduction to other, non-pigmented tissue. Thus, thermal injury to the adjacent tissu is avoided. This is an important aspect of the present invention f5r use on skin lesions, in contact with methods which use continuots wave lasers (including carbon dioxide and argon lasers) producing a much higher degree of thermal injury to the surrounding tissue. Furthermore, pulsed radiation generates an acoustic shock wave at the treatment site, which generally improves the effectiveness 'of the treatment. This appears to be due to the breakup of pigmen :ed particles into smaller pieces which can then be removed by norrr al cellular activity. To generate a shock wave the pulse must be of a duration in the range of 0.1 to 100 microseconds, with an optimu#n duration of between 1 and 5 microseconds.

A tunable or variable wavelength laser may be used to treat skin lesions in several different ways. For example, for complete removal within one or two treatment sessions, the area treated should be in the region of 1 to 3nirr in diameter, per pulse. However, the consequent high energy density results in selective thermal injury and there would be some sca ring, but this will heal well and is not extensive. This process co pares most favourably

with existing practice using, for example, cc rbon dioxide lasers where there is no tissue selectivity and where re Koval of a large area of tissue is required with significant thermal injury and scarring. In effect, when laser apparatus is used in acco dance with the invention it requires much less operator skill since it is less likely to produce accidental or co-lateral thermal damage when compared with existing processes.

In alternative eradication model a spot size of 3 to 5mm may be treated requiring 3 to 4 sessions or each irradiated area. Consequently, this results in much less them al damage but requires a greater number of process sessions.

Again, complete removal of pigmented lesions can be - achieved with no residual scarring at all, butt in this case some 5 to 7 process sessions on a larger site would lie required, resulting in gradual fading of the lesion.

When the process is applied to the eradication of vascular lesions such as "port wine stains", the pulse duration must be selected in the range of 20 to 100 microseconds, whilst the wavelength should be in the region of 500 to 600 nanometres.

Selection of the operating para eters of the laser within the scope of the invention as aforesaid may be made according to the nature of the mark or stain to be removd, and 'of the substrate material.

The laser may be either a flash tube excited laser or a tunable solid state laser such as a titanium sapphire lase-.

It is envisaged that the opera ting ranges of the laser may be selected automatically by a control function which responds to a selection of a mark/substrate type. In 'his way, semi-skilled or perhaps even unskilled technicians may bt capable of eradicating marks and stains effectively.

CLAIMS

1. A method of eradicating mark and stains at or beneath the surface of the substrate, comprising th4 step of directing at said surface, laser light generated by a variablt4 wavelength pulsed laser, the laser operating to produce an outputs in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joule, and at a wavelength in the range of 400 to 900 nanometres.

2. A method according to Claim 1, wherein said pulse duration is in the range of 0.1 to 20 microseconds.

3. A method according to Clain I, wherein said pulse duration is in the range of 20 to 100 microsconds.

4. A method according to Claim 1 or Claim 2, wherein said pulse wavelength is in the range of 400 to 810 nanometres.

5. A method according to Claim 1 or Claim 3, wherein said pulse wavelength is in the range of 500 to 6p0 nanometres.

6. A method according to any pre eding claim, wherein the laser output consists of a sequence of pull as with a repetition rate selectable in the range of 1 to 20Hz.

7. A method according to any preceding claim, wherein the laser energy is delivered to the substrate s rface via an optical fibre

having a core size in the range of 600 to 150pm.

8. Apparatus for eradicating marksi and ' stains at or beneath the surface of a substrate, comprising a variable wavelength pulsed laser adapted to produce an output in the 'arm of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

9. Apparatus according to Claim 8, wherein said pulse duration is in the range of 0.1 to 20 microseconds.

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10. Apparatus according to Claim 18, wherein said laser is adapted to produce a pulse of duration in1the range of 20 to 100 microseconds.

11. Apparatus according to Claim 8 or Claim 9, wherein said laser is adapted to produce a pulse of wavelength in the range of 400 to 800 nanometres.

12. Apparatus according to Claim 8 or Claim 10, wherein said laser is adapted to produce a pulse of wvelength in the range of 500 to 600 nanometres.

13. Apparatus according to Claim 8, in which said laser is adapted to produce a sequence of pulse at a repetition rate selectable from 1 to 20Hz.

14. Apparatus according to any one of Claims 8 to 13, including an optical fibre connected to th output of the laser for delivery of said laser light, and having a ore size in the range of 600 to 1500pm.

15. A method of eradicating skin lesions including pigmented lesions such as tattoo marks, moles, etc. ald vascular lesions such as "port wine stains", the method comprising the steps of directing at the treatment site, laser light generated by a variable wavelength pulsed laser, the laser operating to producel an output in the form of a pulse having a duration in the range of 0.11 to 100 microseconds, at an energy level in the range of 0.5 to 5 Jolules, and at a wavelength in the range of 400 to 900 nanometres.

16. A method according to Claim 15, wherein said pulse duration is in the range of 0.1 to 20 microseconds for removal of pigmented lesions.

17. A method according to Claim 15, wherein said pulse duration is in the range of 20 to 100 microseconds for removal of vascular lesions.

18. A method according to Claim 115 or Claim 16, wherein said pulse wavelength is in the range of 4~0 to 800 nanometres for pigmented lesions.

19. A method according to Claim l 15or Claim 17, wherein

said pulse wavelength is in the range of 540 to 600 nanometres for vascular lesions.

20. A method according to Claim; 15, wherein said pulse duration is in the range of 1 to 5 microseconlds for pigmented lesions.

21. A method according to any oie of CIaims 15 to 20, wherein the laser energy is delivered to the lesion site via an optical fibre having a core size in the range of 600 o 1500pm.

22. A method according to Claim 21, wherein the optical fibre delivery system is hand-held thus to allow adjustment of the spot size of the laser beam on the lesion ite and thus in turn to determine intensity of the energy per pulse g nerated at the site.

INTERNATIONAL SEARCH REPORT

Internatio d Application Igo PCT/GB 92/00739

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, Ine-1cate atp°

According to international Patent Classification (IPC) or to both National Classification and C

Int.C1.5 A 61 B 17/36 B 44 C 1/ 2

11. FIELDS SEARCHED

Minimum Documentation Search

Classification System	Classification S_ bols
Int.C1.5	A61B B44C

Documentation Searched other than Minimum ocumentation s to the Extent that such Documents are Included in t e Fietds Searched

II

Category	Citation of Document. with Indication, where appropriate, of the relevant passages I'	Relevant to Claim No)
	Conference on Lasers and Electro-Opti:s, Baltimore, Maryland, 21-24 May 1985, SSA/IEEE, M.S. SOBEY et al.: "Flashlamp-pumped dye-laser treatment of Dort wine stiins", article WM46	1,2,4,5 ,7-9,11 ,12,14
		3,10
Y	US,A,4829262 (H. FURUMOTO) 9 May 1989, see column 1, line 1 - column 61, line 57	3,10
		1,2,4-9 ,13,14
	EP,A,0377050 (SUMITOMO ELECTRIC INDUSTRIES, LTD) 11 July 1990, see ti* whole document	1,7,8, 14

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° Special categories of cited documents : I0

document defining the general state of the art which Is not considered to be of particular relevance

•Earlier document but published on or after the International filing date

If document which may throw doubts on priority daim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O' document referring to an oral disclosure, use, exhibition or other means

• document published prior to the international filing date but later than the priority date claimed

later doe-ment published after the international filing date or prion date and not to conflict with the application but citedgo Understand the principle or theory underlying the Invei"le

'X' documen of particutar retevance the claimed invention cannot b considered novel or cannot be considered to involve inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Ivtailing of Ibis international Search Report
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M. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Cameo,•	Citation of Dominant, with Indication. where appropriate, of the televat t passages	Relevant to Claim No.
A	EP,A,0172490 (MEDICAL LASER RESEARCH AND DEVELOPMENT CORP.) 26 February 1986, see page 1, line 1 - page 6, line 24; page 11, line 9 - page 16, line 3	1-14
A	WO,A,9012545 (DERMALASE LTD) 1 November 1990, see page 2, line 10 - pain 8, line 16	1,6,13
	Physics in Medicine and Biology, vol. 32, no. 12, December 1987, (Bristol, GB), A.R. HENDERSON et al.: "The 'light touch': a dermatology handpiece designed to improve the efficacy and safety of laser treatment of port-wine stains", pjages 1627-1630	1,7,8, 14

'rnational application No.

INTERNATIONAL SEARCH REPORT

PCT/GB92/00739

Box I XObse nations where certain claims were found unsearchable (Continuation of item I of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. X Claims Nor.: 15 - 22
because they relate to subject matter not required to be searched by this Auth~rity, namely.

Please see Rule 39.1(iv) - PCT:

Method for treatment of the human or animal body by surgery or therapy, as well als diagnostic' methods.

2. Claims Nos.:
because they relate to parts of the international application that do not comp! with the prescribed requirements to such an extent that no meaningful international search can he carried ont, specifcall .

3. D Claims Nos
because they are dependent claims and are not drafted in accordance with the scond and third sentences of Rule 6.4(x).

Box II Observations where unity of invention is lacking (Continuation nf item of first sheet)

This International Searching Authority. found multiple inventions in this international triplication, as follows:

1. ~7 As all required additional search fees were timely paid by the applicant, this int4rrtational search report covers all searchable claims.

2. f As all searchable claims could be searches without effort jnstifying an addition a4 fee, this Authority did not Invite payment of any additional fee.

3. [] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid hy the applicant. Conseque tly, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims 'as.:

Remark on Protest

F1 The additional search fees were accompanied hy the applicant's protest.

No protest accompanied the payment of additonal search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLI ATION NO. GB 9200739

SA 58731

Thin annex lists the patent *family* members relating to the patent docnments cited in above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 16/07192
The European Patent Office is in no way liahle for these particulars *which* are merely iven for the purpose of information.

Patent document cited its search report	Publication date	Pater t family metaber(s)	Publication date
US-A- 4829262	09-05-89	US-A- 5066293	19-11-91
EP-A-			
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